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(54) **Apparatus for separating mixtures of liquid and gas.**

(57) Apparatus for separating mixtures of liquid and gas, comprising a first stage separator and a second stage separator. The first stage separator comprises a tubular wall 2 defining an inner space 3 and an outer space 6. Swirl imparting means 10 are provided for imparting a rotary movement to a gas/liquid mixture supplied into said inner space to separate the liquid and the gas. In the tubular wall 2 at least one opening 12 is arranged for discharging the separated liquid from the inner space 3 into the outer space 6. A primary gas outlet tube 13 having the lower end positioned inside the inner space 3 is provided for discharging substantially liquid-free gas from the inner space. A secondary gas outlet is provided for dicharging gas from the outer space. The secondary gas outlet 16 is in fluid communication with the inlet of the first stage separator, which first stage separator further operates as a second stage separator to separate liquid from the gas stream discharged from the outer space.

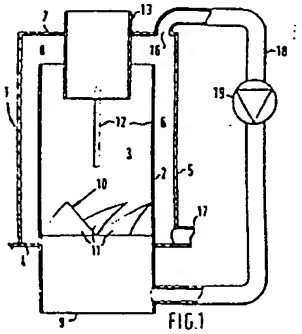

FIG.1

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APPARATUS FOR SEPARATING MIXTURES OF LIQUID AND GAS

The present invention relates to an apparatus for separating mixtures of liquid and gas. The invention relates more in particular to such an apparatus comprising a normally vertically extending tubular wall defining an inner space and an outer space, a top wall arranged at some distance above the tubular wall and confining said inner space and said outer space in upward direction, inlet means for supplying a mixture of a liquid and a gas into the inner space, swirl imparting means inside the inner space for imparting a rotary movement to the mixture of the liquid and the gas to separate the liquid and the gas and outlet means for separately discharging the liquid and the gas from the inner space.

The term gas is taken throughout the specification and the claims also to include vapour.

Apparatuses of the above-mentioned type are suitable for use in columns for separating liquid/gas mixtures, as well as in columns for contacting a liquid with a gas for creating an exchange of matter and/or heat between the phases, followed by a separation of the phases. The apparatuses are thereto mounted in or over openings in trays arranged in such columns.

An example of the above-mentioned apparatus for separating mixtures of liquid and gas is described in co-pending European patent application 81200963.7 published under publication number 0048508 on 31st March 1982. This earlier apparatus is provided with a primary gas outlet tube for discharging gas directly from the inner space and a secondary gas outlet tube for discharging gas from the outer space, which gas has been entrained by the liquid discharged from the inner space. In the earlier apparatus the gas from the primary gas outlet tube and the gas from the

secondary gas outlet tube are directly united after leaving the relevant outlet tubes. By applying a primary gas outlet tube having a lower end with a cross-sectional area which is relatively small compared with the cross-sectional area of the inner space and arranging said lower end of the primary gas outlet tube below the upper end of the tubular wall, a substantially liquid-free gas stream may be discharged via the primary gas outlet tube. Especially at relatively high liquid loads and/or relatively high flow velocities, however, it may occur that the gas stream from the secondary gas outlet tube contains some liquid entrained from the outer space. As a consequence of the above, the final gas product from the earlier apparatus may still contain minor amounts of liquid.

The object of the present invention is to improve the above earlier type of apparatus in order to obtain an apparatus enabling the separation of liquid/gas mixtures in substantially gas-free liquid and substantially liquid-free gas even at high liquid loads and high flow velocities.

The apparatus for separating mixtures of liquid and gas thereto comprises according to the invention a first stage separator and a second stage separator, the first stage separator comprising a normally vertically extending tubular wall defining an inner space and an outer space, a top wall arranged at some distance above the tubular wall and confining said inner space and said outer space in upward direction, inlet means for supplying a mixture of a liquid and a gas into the inner space, swirl imparting means inside the inner space for imparting a rotary movement to the mixture of the liquid and the gas to separate the liquid and the gas, outlet means for separately discharging the liquid and the gas from the inner space, said outlet means comprising a primary gas outlet tube arranged substantially coaxially with the inner space, passing through the top wall and having the lower end thereof positioned inside the inner space below the upper end of the tubular wall, and at

least one liquid discharge opening arranged in the tubular wall, the first stage separator further comprising at least one secondary gas outlet for discharging gas from the outer space, wherein the second stage separator is provided with an inlet being in fluid communication with the secondary gas outlet, and means for separately discharging liquid and gas from the second stage separator.

In a suitable embodiment of the invention the first stage separator and the second stage separator are substantially identically shaped.

In another suitable embodiment of the invention the second stage separator is formed by the first stage separator. In this embodiment the first stage separator is provided with a return loop forming a fluid communication between the secondary gas outlet and the inlet means of said first stage separator.

In a further suitable embodiment of the invention the second stage separator comprises filter means for separating the liquid and the gas discharged via the secondary gas outlet, wherein the upper end of the primary gas outlet tube is arranged above the filter means.

In the apparatus according to the invention the gas from the secondary gas outlet is passed to a second stage separator for removing the liquid entrained by the gas from said secondary gas outlet, prior to uniting the gas from the primary outlet tube and the gas from the secondary gas outlet.

In the apparatus described in the co-pending European patent application 81200963.7 the gas from the secondary gas outlet is directly added to the gas from the primary gas outlet tube, so that at high liquid loads and/or flow velocities the quality of the substantially liquid-free gas from the primary gas outlet tube may be adversely affected by relatively wet gas from the secondary gas outlet. For further drying the gas the whole mass of gas from the primary gas outlet tube and the secondary gas outlet must be treated when using the above known

apparatus. In the now proposed apparatus, however, only a small portion of the total mass of gas, viz. only the gas from the secondary gas outlet need to be further treated, for obtaining a substantially liquid-free total mass of gas. The second stage separator for treating the gas from the secondary gas outlet according to the invention may therefore be relatively small-sized in case of the application of a separate second stage separator. Further, the apparatus according to the invention may be operated at liquid loads and/or flow velocities, giving rise to a less efficient separation in the known apparatus. As a consequence thereof the size of the apparatus according to the invention designed for a given throughput may be reduced compared with the known apparatus, which results in a considerable cost reduction.

The invention will now be described by way of example only in more detail with reference to the accompanying drawings, wherein:

Figure 1 shows a vertical section of an apparatus according to the invention for separating mixtures of liquid and gas;

Figure 2 shows a vertical section of the lower part of a second embodiment according to the invention;

Figure 3 shows a vertical section of the lower part of a third embodiment according to the invention; and

Figure 4 shows a vertical section of the lower part of a fourth embodiment according to the invention.

It will be understood that the elements shown in one embodiment of the invention may be applied individually to the several other embodiments shown in the drawings.

It is noted that identical elements shown in the drawings have been indicated with the same reference numeral.

Figure 1 shows an apparatus according to the invention for separating mixtures of liquid and gas, which apparatus is indicated hereinafter with the expression "swirl tube".

The swirl tube 1 comprises a tubular wall 2 enclosing an inner or separating space 3. The tubular wall 2, being mounted in an opening of a bottom wall 4, is surrounded by an enveloping wall 5. Between the tubular wall 2 and the enveloping wall 5 an outer or liquid discharge space 6 is present, said outer space 6 being confined in downward direction by the bottom wall 4 and in upward direction by a top wall 7. Said top wall 7 is arranged at some distance above the upper end of the tubular wall 2, thereby creating a fluid passage 8 between the inner space 3 and the outer space 6. Through the open lower end 9 of the swirl tube 1 a mixture of liquid and gas can be supplied to a vane assembly 10 consisting of a plurality of blades 11 and being arranged inside the inner space 3. The tubular wall 2 of the swirl tube 1 is provided with a number of liquid discharge openings 12, equally distributed along the periphery of said wall 2 and positioned downstream of the vane assembly 10.

A primary gas outlet tube 13 passing through an opening in the top wall 7 has its lower end 14 arranged below the upper end 15 of the tubular wall 2, thereby extending into the separating space 3. The primary gas outlet tube 13, vane assembly 10 and separating space 3 are substantially co-axially arranged relative to each other. The top wall 7 is further provided with an opening 16 forming a secondary gas outlet for discharging gas from the liquid discharge space 6. An outlet tube 17 having one end thereof arranged in an opening in the lower part of the enveloping wall 5, serves to discharge liquid from the liquid discharge space 6. Finally, the swirl tube 1 comprises a conduit 18 provided with a fan 19, forming a fluid communication between the opening 16 and the inlet part of the separating space 3.

In operation, a mixture of liquid droplets and gas is introduced into the separating space 3 of the swirl tube 1 via its opening 9. In the separating space 3 the gas/liquid mixture passes through the vane assembly 10, whereby the blades 11 of

said vane assembly 10 impart a rotary movement to the gas/liquid mixture. By this rotary movement the liquid droplets of the gas/liquid mixture are flung outwardly to impinge and coalesce on the inner surface of the tubular wall 2. The liquid layer which is so formed on the inner surface of the tubular wall 2 passes partly through the liquid discharge openings 12 in the tubular wall 2 and partly through the fluid passage 8. The separated liquid is collected in the liquid discharge space 6 and is subsequently discharged from said space 6 via the liquid outlet tube 17.

The major part of the gaseous components of the gas/liquid mixture supplied into the swirl tube 1, is discharged from the separating space 3 via the primary gas outlet tube 13. In order to prevent entrainment of liquid collected on the inner surface of the tubular wall 2 by the gas discharged via the primary gas outlet tube 13, the cross-sectional area of the primary gas outlet tube 13 should be substantially smaller than the cross-sectional area of the separating space 3. A suitable cross-sectional area of the primary gas outlet tube 13 may be chosen within the range of 15 through 65 per cent of the cross-sectional area of the separating space 3. In this range of cross-sectional areas the gas passing through the primary gas outlet tube 13 will be substantially liquid-free, without an inadmissible increase of the pressure drop over the swirl tube 1.

The liquid separated from the gas stream by the action of the vane assembly 10 and entering into the liquid discharge space 6 may contain small amounts of entrained gas. This gas is discharged from said liquid discharge space 6 via the secondary gas outlet 16. Especially at high liquid loads and/or high flow velocities in the swirl tube 1, it may happen that liquid is entrained by the gas leaving the liquid discharge space 6 via the secondary gas outlet 16. To prevent that in this case the quality of the gas stream from the primary gas outlet tube 13 is adversely affected by wet gas from the secondary gas outlet 16

upon admixture therewith, the secondary gas stream is further treated to separate the liquid therefrom. To this end the secondary gas stream is recirculated to the inlet part of the separating space 3 via conduit 18 by the action of the fan 19.

In the embodiment shown in Figure 1 swirl tube 1 not only functions as a first stage separator for the main separation of the introduced gas/liquid mixture but also as a second stage separator for the removal of liquid from the secondary gas stream. By the above-described arrangement gas/liquid mixtures can be separated even at very high liquid loads and flow velocities in substantially liquid-free gas and substantially gas-free liquid.

The application of a secondary gas outlet tube passing through the top wall 7 and having its lower end arranged below the lower surface of said top wall 7, as proposed in European co-pending patent application 81200963.7 to reduce entrainment of liquid by the gas stream leaving the liquid discharge space 6, is in the embodiment of the present invention shown in Figure 1 superfluous since the secondary gas is subjected to a further treatment for drying the gas.

Reference is now made to Figure 2 showing part of a further embodiment of the invention. In this Figure the bottom part of a column generally indicated by reference numeral 20, for separating gas/liquid mixtures, has been depicted.

The column 20 having a tubular shell 21 is provided with means for the supply into and the discharge from the interior of the column 20 of fluids. These means comprise an inlet 22 for the supply of a mixture of liquid and gas, a liquid outlet 23 for discharging separated liquid and a not shown gas outlet for discharging separated gas arranged in the upper part of the column 20.

A substantially horizontally arranged tray 24 provided with a plurality of swirl tubes 25 mounted in openings thereof, is positioned in the interior of the column 20. Substantially

parallel to the tray 24, a top wall 26 is arranged at some distance above the upper ends of the swirl tubes 25. The space 27 surrounding the swirl tubes 25 and confined by the tray 24, the top wall 26 and the tubular shell 21 is indicated hereinafter with the expression outer or liquid discharge space. A further wall 28 is arranged at some distance above the top wall 26 thereby forming a space 29 for collecting secondary gas from the swirl tubes 25. The secondary gas-collecting space 29 is in fluid communication with the column inlet 22 via a conduit 30 provided with a throat-shaped end 31 arranged in the centre of a venturi 32 of the inlet 22. The venturi 32 creates a suction in the inlet 22 so that gas in the secondary gas-collecting space 29 is forced to flow via conduit 30 to the column inlet 22.

The swirl tubes 25 each comprise a tubular wall 33 enclosing an inner or separating space 34 in which space a vane assembly 35 is arranged for imparting a rotary movement to a gas/liquid mixture supplied via the inlet 22. The tubular walls 33 are each provided with liquid discharge openings 36 for withdrawing separated liquid from the inner spaces 34. A plurality of primary gas outlet tubes 37 pass through openings in the top wall 26, and have their lower ends positioned inside the inner spaces 34 below the upper ends of the tubular walls 33. For discharging gas from the liquid discharge space 27 into the secondary gas-collecting space 29, the top wall 26 is further provided with a plurality of openings 38.

During operation of the apparatus shown in Figure 2 a gas/liquid mixture is supplied to each of the swirl tubes 25 via a common inlet formed by the column inlet 22. Upon passing the vane assemblies 35 a rotary movement is imparted to the gas/liquid mixture, causing a separation of the liquid from the gas. The liquid leaves the swirl tubes 25 partly via the passages between the upper ends of the tubular walls 33 and the top wall 26 and partly via the liquid discharge openings 36. The liquid collected in the liquid discharge space 27 is withdrawn from the

column 20 via the liquid outlet 23. A substantially liquid-free gas leaves the swirl tubes 25 via the primary gas outlet tubes 37 and enters the part of the column 20 above the wall 28, where the gas may be further treated or directly discharged from the interior of the column 20.

Gas entrained by the liquid leaving the swirl tubes 25 flows in upward direction through the openings 38 in the top wall 26 and enters the secondary gas-collecting space 29. Due to the suction action of the venturi 32 in the inlet 22 the gas is forced to flow from the secondary gas-collecting space 29 via the conduit 30 to the inlet 22. The secondary gas from conduit 30 subsequently flows to the swirl tubes 25 for a further treatment of the gas to separate the liquid therefrom.

The swirl tubes 25, like the swirl tube 1 shown in Figure 1, operate not only as first stage separators for separating the bulk of gas and liquid but also as second stage separators for further drying the secondary gas obtained in the main separation.

Reference is now made to Figure 3 showing a further embodiment of the invention. In this embodiment the recirculating system for a further treatment of the secondary gas, as shown in Figure 2, has been replaced by filter means, generally indicated with reference numeral 40 arranged around the primary gas outlet tubes 37. The filter means 40 comprises a layer 41 of closely packed fibres, for example made of stainless steel, arranged between a pair of perforated walls 42, secured to the tubular shell 21 of column 20. The venturi-shaped inlet 22, essential in the recirculating system as shown in Figure 2, has been replaced by a conventional inlet 43 arranged in the bottom part of the column 20. Apart from the liquid outlet 23 the column partly shown in Figure 3 is provided with a further liquid outlet 44 for withdrawing liquid separated by the filter means. For removing secondary gas from the liquid discharge space 27 a plurality of secondary gas outlet tubes 45 pass through openings in the top wall 26.

During operation of the apparatus shown in Figure 3 substantially liquid-free gas separated from a mixture of liquid and gas supplied via the inlet 43 to the swirl tubes 25 forming the first stage separators is discharged via the primary gas outlet tubes 37. The gas entrained by the liquid discharged from the swirl tubes 25 pass through the secondary gas outlet tubes 45 and subsequently enters the filter means 40, forming the second stage separator. In the filter means 40, entrained liquid droplets are separated from the secondary gas, so that substantially liquid-free secondary gas leaves the filter means 40 via the upper perforated wall 42. The liquid separated from the gas passing through the filter means 40 is withdrawn from the column via the liquid outlet 44. By the arrangement of the secondary gas outlet tubes 45 having their lower ends arranged below the lower surface of the top wall 26, the risk of entrainment of liquid by the secondary gas is already considerably reduced so that even at high liquid loads and/or flow velocities only minor amounts of liquid have to be separated by the filter means 40.

In Figure 4, a further alternative of the apparatus shown in the preceding Figures, has been depicted. In this embodiment of the present invention the column 20 is provided with a conduit 50 forming a fluid communication between the secondary gas-collecting space 29 and the inlet of a swirl tube 25. During operation of the apparatus shown in Figure 4, gas from the secondary gas outlet tubes 45 is collected in the secondary gas-collecting space 29, whereas substantially liquid-free gas from the primary gas outlet tubes 37 enters the part of the column arranged above the wall 28. Due to the pressure difference over the primary gas outlet tubes 37, the secondary gas is urged to flow from the secondary gas-collecting space 29 to a swirl tube 25 via conduit 50. In this swirl tube, operating as a second stage separator, the liquid entrained by the secondary gas is separated and withdrawn from the gas, so that substantially liquid-free gas leaves the relevant swirl tube 25 via the accompanying primary gas outlet tube 37.

Although in the last-mentioned embodiment of the invention the swirl tube 25 operating as the second stage separator is arranged at the same level as the other swirl tubes, operating as first stage separators, it will be understood that the second stage separator may also be arranged at a level different from the level at which the first stage separators are arranged. The second stage separator may, for example, be mounted in an opening of the wall 28. In such an arrangement the conduit 50 for recirculating the secondary gas is deleted, whereas the second stage separator should be provided with a separate space for collecting the liquid separated in this second stage separator.

Although Figure 3 shows an embodiment of the invention, wherein filter means in the form of closely packed fibres are applied as a second stage separator, it will be understood that any other type of filter means may be applied, such as baffles or vanes being inclined with respect to the flow direction of the secondary gas.

In the shown drawings the swirl tubes are mounted in openings of a wall. It should be understood that it is also possible to arrange the swirl tubes over openings of a wall.

The swirl tubes 1 and 25 shown in the drawings may be provided with mixing chambers, communicating with the lower ends of said swirl tubes, as described in the co-pending European patent application 81200963.7. In this case the column in which the swirl tubes are applied should be provided with separate inlets for liquid and gas.

CLAIMS

1. Apparatus for separating mixtures of liquid and gas, characterized in that is comprises a first stage separator and a second stage separator, the first stage separator comprising a normally vertically extending tubular wall defining an inner space and an outer space, a top wall arranged at some distance above the tubular wall and confining said inner space and said outer space in upward direction, inlet means for supplying a mixture of a liquid and a gas into the inner space, swirl-imparting means inside the inner space for imparting a rotary movement to the mixture of the liquid and the gas to separate the liquid and the gas, outlet means for separately discharging the liquid and the gas from the inner space, said outlet means comprising a primary gas outlet tube arranged substantially co-axially with the inner space, passing through the top wall and having the lower end thereof positioned inside the inner space below the upper end of the tubular wall and at least one liquid discharge opening arranged in the tubular wall, the first stage separator further comprising at least one secondary gas outlet for discharging gas from the outer space, wherein the second stage separator is provided with an inlet being in fluid communication with the secondary gas outlet, and means for separately discharging liquid and gas from the second stage separator.

2. Apparatus as claimed in claim 1, characterized in that the first stage separator and the second stage separator are substantially identically shaped.

3. Apparatus as claimed in claim 1, characterized in that the second stage separator is formed by the first stage separator.

4. Apparatus as claimed in claim 1, characterized in that the second stage separator comprises filter means and wherein the primary gas outlet tube passes through said filter means.

5. Apparatus as claimed in claim 4, characterized in that the filter means comprises a layer of closely packed fibres held under pressure by a pair of substantially parallel perforated walls.

6. Apparatus as claimed in claim 4, characterized in that the filter means comprises a plurality of inclined vanes, the upper end of the primary gas outlet tube being arranged above said vanes.

7. Apparatus as claimed in any one of the claims 1 through 6, characterized in that it comprises a plurality of first stage separators, being mounted in or over openings in a wall, and having common inlet means for supplying a mixture of a liquid and a gas into the inner spaces defined by the tubular walls of said first stage separators.

8. Apparatus as claimed in claim 7, characterized in that it comprises a plurality of second stage separators formed by the first stage separators and means forming a fluid communication between the secondary gas outlets of the first stage separators and the common inlet means.

9. Apparatus as claimed in claim 7, characterized in that it comprises at least one second stage separator having a shape substantially identical to that of a first stage separator.

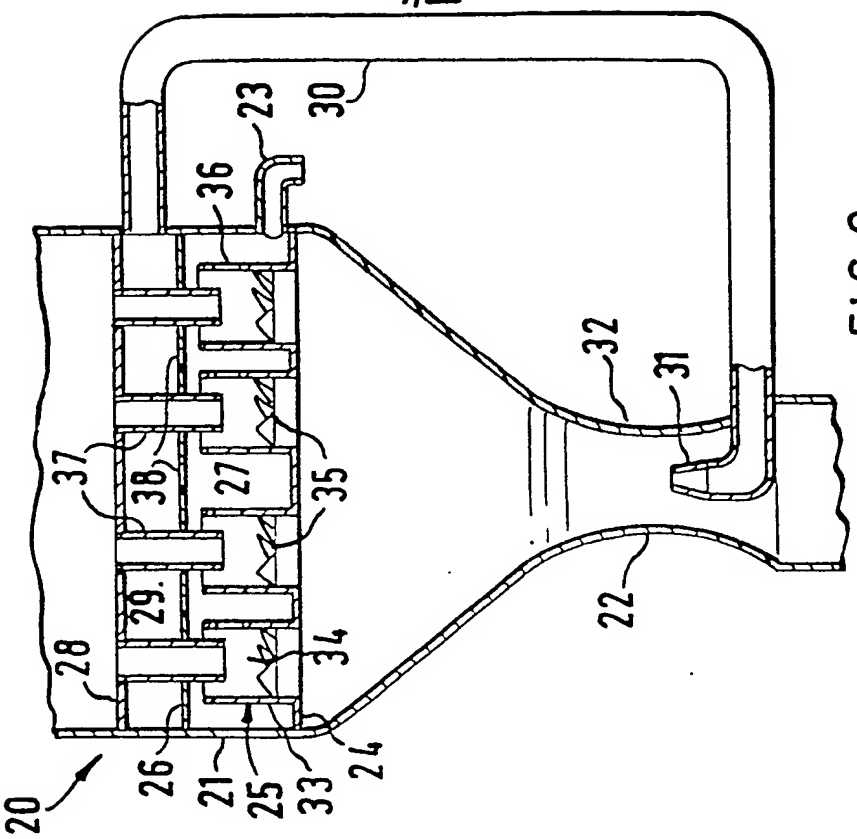
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FIG.2

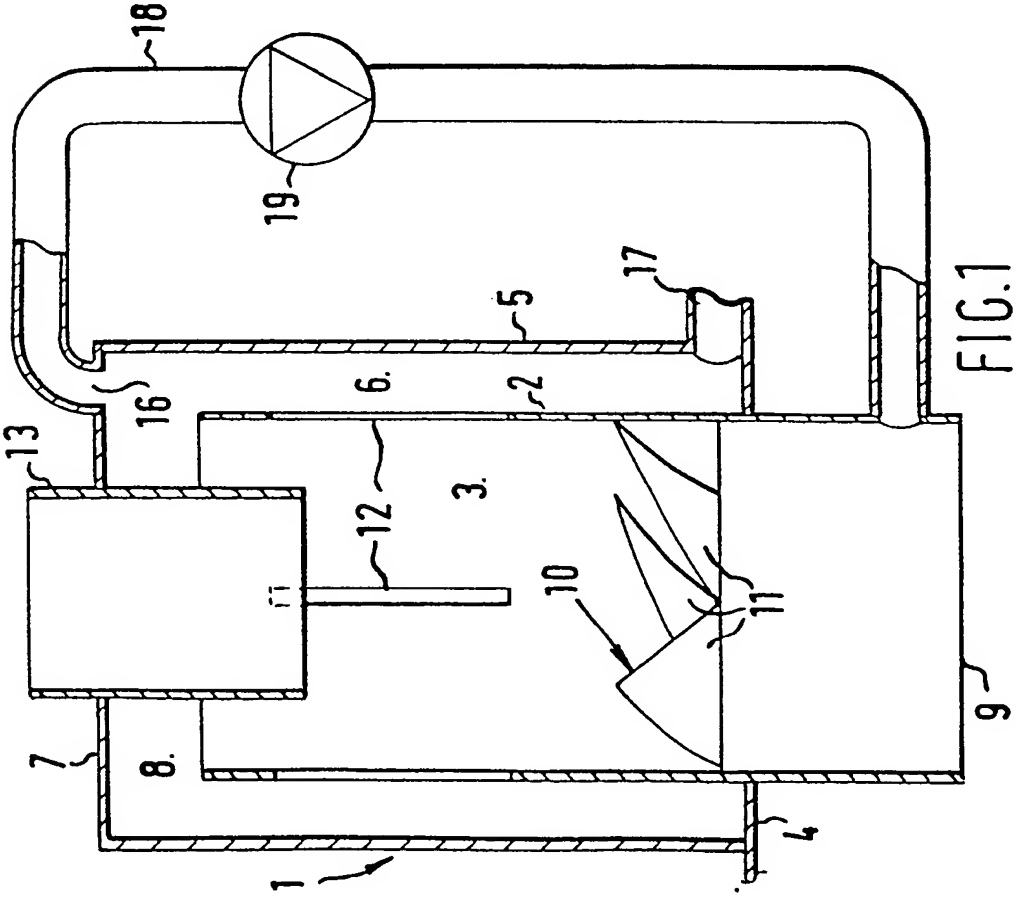
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FIG.1

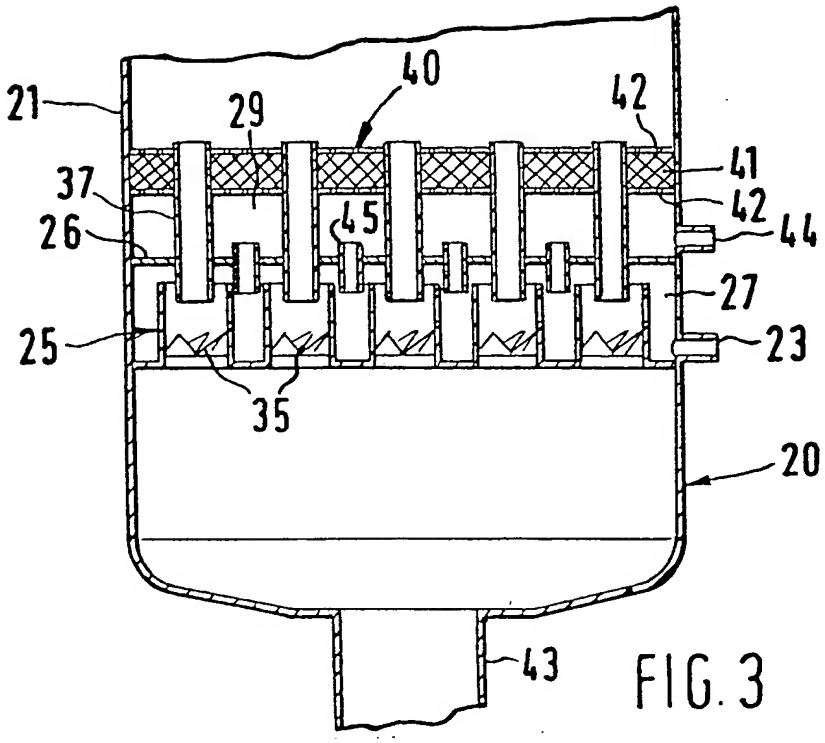
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FIG. 3

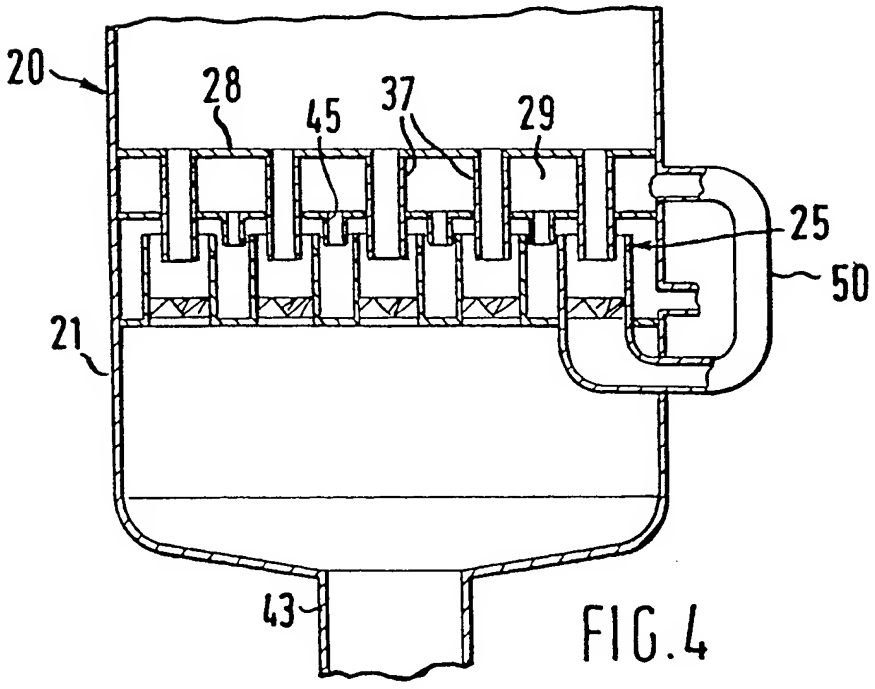
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FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

0083811

Application number

EP 82 20 1420

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
D,A P	EP-A-0 048 508 (SHELL INTERNATIONALE RESEARCH) * Claims 1-10; figures 1, 3 *	1,7,8	B 01 D 45/12
A	WO-A-8 101 961 (M. GEISSMANN) * Claims 1-3, 6-8; figures 3,4 *	1-3	
A	DE-B-1 769 240 (PORTA-TEST MFG) * Claim 1; figure 1 *	1-3	
A	DE-A-2 818 510 (U. REGEHR) * Claim 1; figure 1 *	1	
A	US-A-2 625 240 (C.B. McBRIDE et al.) * Claim 1; figures 1, 5; column 4, lines 59-69 *	1,7,8	

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

B 01 D 45/00
B 01 D 47/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	04-03-1983	BERTRAM H E H

CATEGORY OF CITED DOCUMENTS

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